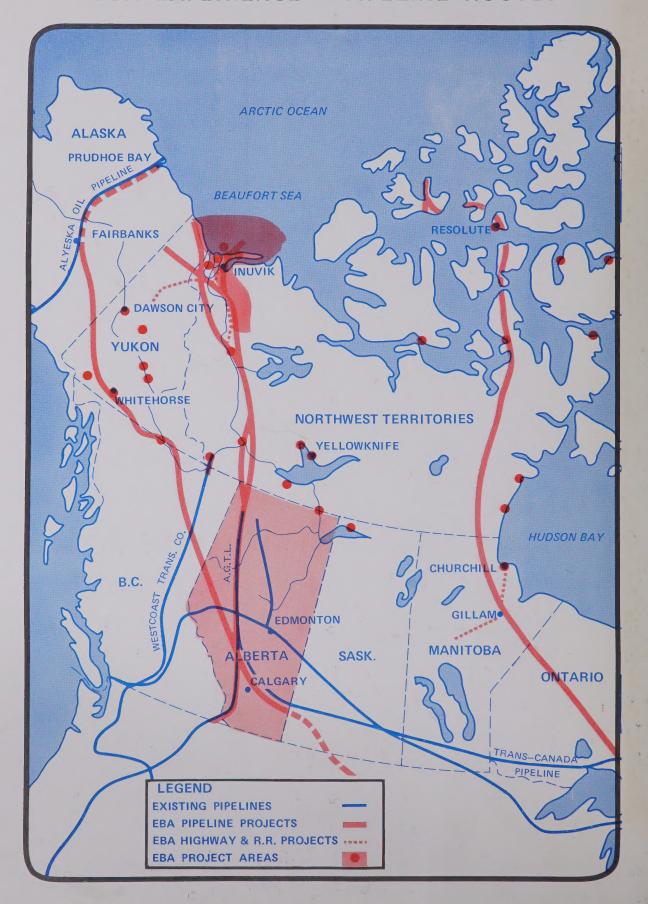


## EBA EXPERIENCE - PIPELINE ROUTES



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### 1.0 INTRODUCTION

Numerous engineering challenges are associated with exploration for and development of northern oil and gas resources. EBA Engineering Consultants Ltd. has worked toward meeting this challenge on many projects over the past ten years. EBA is a western Canadian firm that is entirely owned and operated by practicing professionals. It was incorporated in 1966 to provide specialized consulting services in the field of earth science engineering. During the past decade, EBA's staff has grown to include more than 100 professional, technical, and support personnel located in modern office and laboratory facilities in Edmonton and Calgary.

EBA professional staff have gathered consulting experience that totals in excess of 200 man-years. A balance is maintained between civil engineers, engineering geologists, and geologists. This provides the ability to combine both engineering and geological perspectives, as is often required on large projects. EBA's professionals are supported by skilled staff and modern equipment in providing laboratory, secretarial, graphics, and printing services.

#### 2.0 NORTHERN EXPERIENCE

Since 1966, EBA Engineering Consultants Ltd. has initiated more than 250 different projects in northern Canada. These projects have ranged in magnitude from long-term, multi-phase field programs, to small site investigations. The variety of work undertaken has included performing complex analyses, formulating recommendations for site development, and presenting foundation design parameters. The sections which follow outline EBA's involvement in Arctic Geotechnical Engineering.

### 2.1 Major Route Engineering Studies

- Polar Gas Project Melville Island to Longlac,
  Ontario
- Foothills Pipe Line Ltd. AlCan and Mackenzie
  Valley Routings
- Alberta Gas Trunk Line Northern and Western Alberta
- Alberta Gas Trunk Line Arctic Pilot Project,
  Melville Island
- Hudson Bay Railway Northern Manitoba
- Canadian Arctic Gas Study Ltd. Mackenzie Valley
- Beaufort Delta Oil Project Ltd. Offshore Pipeline
- Mackenzie Highway Norman Wells to Fort Good Hope, N.W.T.
- Arctic Railway (for CNR and CPR) East Alternative
  Norman Wells to Richards Island

The extent of EBA's involvement in all of the pipeline and corridor studies cited above has been substantial. The scope of EBA's geotechnical contribution to the Polar Gas Project is of particular note, since EBA has functioned as sole geotechnical

consultant for the 2500 mile land pipeline feasibility study. This involvement over the past several years has included a major commitment of engineering personnel to the following tasks:

- Planning and executing helicopter-borne drilling programs to drill and obtain samples from more than 1000 boreholes located in some of Canada's most remote areas
  - Installing numerous ground temperature sensors

Conducting a geotechnical overview of specific problem areas such as river crossings and critical slopes

- Developing designs to accommodate frost heave for a chilled pipe in unfrozen riverbeds
- Developing designs to accommodate thaw settlement experienced by a warm pipeline in discontinuous permafrost
- Developing conceptual designs for access roads and work pads
- Assessing sites selected for compressor stations, camps, and related facilities

- Conducting trial ditching studies and evaluating blasting excavation methods in permafrost
- Preparing geotechnical portions of the application documents
- Evaluating borrow prospects and developing a philosophy for borrow development to be incorporated in the construction plan

### 2.2 Granular Construction Materials

- Granular Construction Materials Evaluation Polar
  Gas Pipeline Corridor
- Gravel Pit Evaluation and Development Study Ya Ya Lake, Richards Island, N.W.T.
- Evaluation of Borrow Quality Dempster Highway,
  Yukon Territory
- Granular Resource Evaluation Alaska Highway near Haines, Yukon Territory
- Regional Evaluation of Granular Resources Lower Mackenzie Valley, N.W.T.

- Detailed Investigation of Several Granular Deposits - Mackenzie Delta, N.W.T.
- Evaluation of Rock Quarry Potential Inuvik Area,
  N.W.T.
- Regional Exploration for Granular Resources to be used in Constructing Artificial Drilling Islands -Beaufort Sea, Offshore

Consulting experience on granular construction materials in permafrost regions has been more comprehensive than routine field investigations and report preparation. EBA staff have worked directly on field operations such as exploitation of gravel from the Ya Ya Lake esker on Richards Island. This and other experience gained in the Mackenzie Delta has been summarized in a paper presented at the 1977 annual meeting of the Canadian Institute of Mining and Metallurgy in Ottawa.

## 2.3 Arctic Offshore Investigation and Design

- Investigation of seabed conditions at sites for drilling islands in the Beaufort Sea
  - Assessment of potential submarine borrow pits for constructing islands placed by hydraulic filling methods

- Design of a drilling island located in Mackenzie Bay
- Analysis of the overall stability of drilling islands
- Analysis of stresses and settlements anticipated for a drilling island retained by steel caissons
- Shallow siesmic surveys, ice scour investigations, and geotechnical assessment of seabed materials for a submarine pipeline, Beaufort Sea

### 2.4 Applied Research and Geo-Analytical Studies

- Analysis and prediction of frost heave beneath chilled gas pipelines
- Analysis and design of foundations for heated structures on permafrost, including oil storage tanks
- Installation of instrumentation and analysis of performance data for a gas pipeline test facility at Norman Wells, N.W.T.
- Development of numerical modelling techniques for geothermal studies

- Thermal analysis of roadway fills and construction pads placed on permafrost
- Performance appraisal of impermeable liners for hydrocarbon storage facilities in Arctic areas

EBA has been instrumental in the development of a two-dimensional finite element computer program to analyze heat transfer as it pertains to the aggradation or degradation of permafrost. This program and extensions of it have been used to verify several different proposals for pipeline designs where the processes of thaw settlement or frost heave were important issues.

# 2.5 Geotechnical Engineering of a General Nature for Northern Regions

- Site investigations and foundation design recommendations for gas plants, residences, schools, warehouses, apartments, and docks throughout the Canadian north
- Geotechnical analyses and design for municipal facilities, including reservoirs, water and sewage systems, utilidors and roads
- Foundation design for compressor stations and electrical generating plants.

- Slope stability analyses for pipeline river crossings, road cuts, and earth structures
- Site evaluations and foundation designs for tank farms throughout the lower Mackenzie Valley
- Development of stabilization and remedial measures for structures damaged by thaw settlement or frost heave
- Geophysical delineation of granular borrow sources and permafrost conditions

EBA has been active in formulating foundation recommendations and monitoring construction for buildings and municipal works throughout the Yukon, and has collected most of the geotechnical data available for the communities of Dawson City, Ross River, and Faro. Local site investigations have also been conducted at nearly all of the communities along the Alaska Highway, including a substantial volume of work at Whitehorse and in the surrounding area.

## 2.6 <u>Innovations in Northern Geotechnical Consulting</u>

EBA's involvement in northern projects since 1969 has resulted in the development of some innovative solutions to problems unique to permafrost regions. These innovations include the following:

- Modification of the CRREL ice coring auger for sampling frozen soils
- Formulation of design requirements for heliportable auger drills
- Adaptation and design of a drill rig and refrigeration unit to conduct an extensive sampling program in frozen bouldery tills and gravel that are typical of the District of Keewatin, N.W.T.
- Adaptation of a high frequency vibratory drill for use in extensive sampling programs in permafrost soils
- Routine use of mobile field laboratories to minimize requirements for sample shipment, and to improve the quantity and quality of test data obtained from field programs in remote areas
- Development of reliable instrumentation for monitoring ground temperatures

Development of an automatic warning system to detect lateral movement resulting from ice pushing on artificial islands in the Beaufort Sea

- Application of two-dimensional geothermal analyses to the design of foundation systems
- Design of heated, slab-on-grade structures on permafrost soils stabilized with Cryo-anchor heat pipes
- Development of a computerized data bank for storage and retrieval of borehole and laboratory data

### 3.0 FBA RESOURCES

### 3.1 Key Personnel

EBA has more than 35 professionals on staff, most with postgraduate training and related experience in the fields of:

- arctic geotechnical engineering
- geotechnical engineering
- engineering geology
- rock mechanics
- hydrogeology
- materials engineering
- transportation engineering

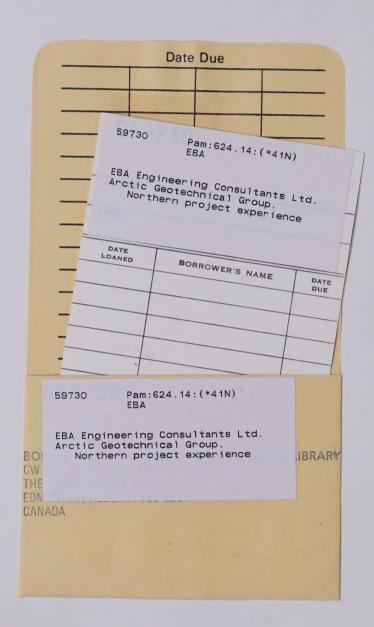
Among EBA's professional staff are seven professional engineers and geologists designated as the Arctic Geotechnical Group. This group is involved solely in projects where permafrost is a dominant design factor. This degree of specialization ensures

that the consultant is fully aware of all aspects that affect conducting a program of investigation in remote northern regions.

### 3.2 Project Management

EBA staff recognize the importance of scheduling, cost control, and prompt communication with the client. Through involvement in a variety of engineering studies, EBA has developed project management capabilities so that investigative and design programs can be administered effectively.





# **EXPERIENCE**

RELIABILITY

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